**Urban Utilities Planning: Water Supply, Sanitation and Drainage**
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**Module - 04**
**Pumping and Storage**
**Lecture - 19**
**Service Reservoir - Part I**

Welcome back. In Lecture 19 we will talk about Service Reservoirs. And service reservoirs will be covered in 2 lectures Part 1 and Part 2.

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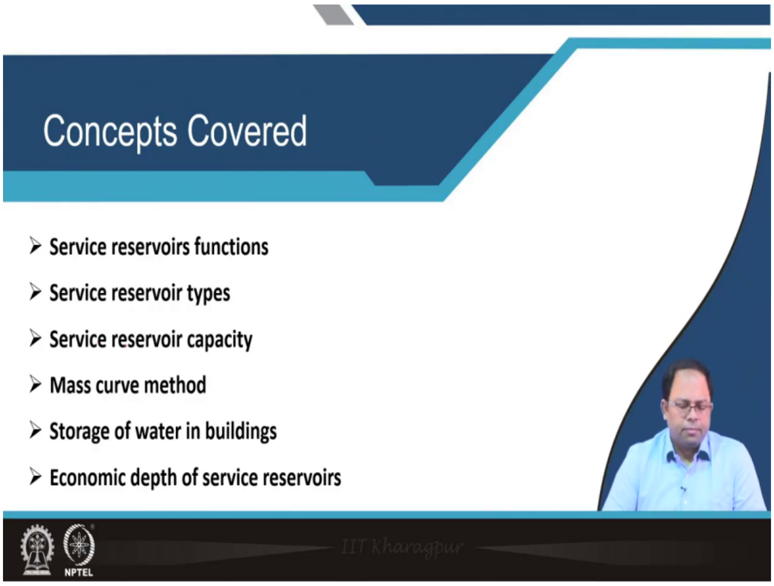


So, the different concepts that we will cover in this lecture are service reservoir functions, service reservoir types, service reservoir capacity and we will determine service reservoir capacity using mass curve method, storage of water in buildings and economic depth of service reservoirs.

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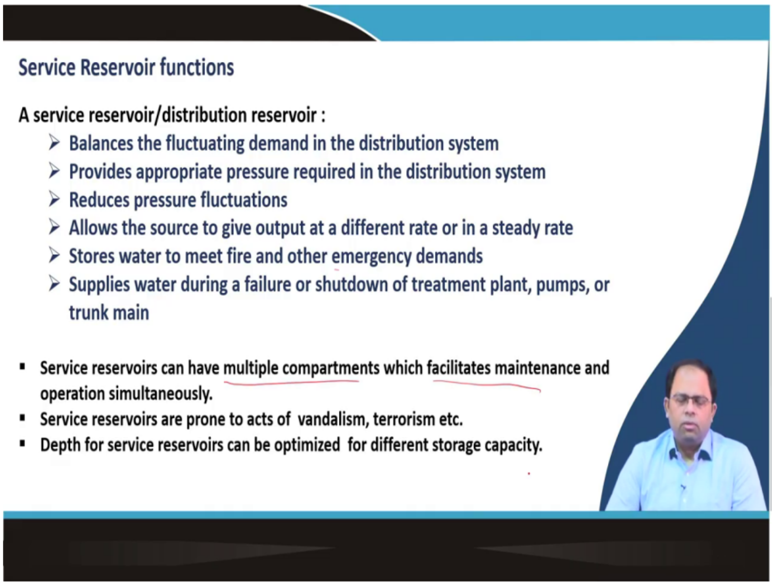


**Service reservoir function**

When we talk about service reservoir function, there are different kinds of service reservoirs. We have dams which are sort of reservoirs where we store water. Independent of the variation of river flow in different seasons, we can draw water out of the reserve for irrigation or for other urban consumption purposes equally at different seasons. But whenever we require a reservoir inside a water supply network, we call it a service reservoir (overhead tanks in most cases).

A service reservoir or a distribution reservoir of a water supply network is actually required so that we can balance the fluctuating demand in the distribution system. We have already discussed that the water demand is different during different seasons, during different months, during different days of the week and during different hours of the day. Because of this different consumption pattern, we need to supply varying amount of water at different time periods. Similarly, when we need to fill up the tank we can supply the tank with certain speed using pumps throughout the day; that means, there pumps will be operating for 24 hours. But usually it is not so. We will run the pump for maybe 2 or 3 periods. So, both demand and supply in the distribution system is fluctuating and can be balanced by the presence of a service reservoir.

A service reservoir is responsible for providing appropriate pressure required in the distribution system. Because the service reservoir can be lifted to a certain height, automatically the water is raised at a particular level. So, if the reservoir is at a height of 20 meters, then we say that 20 meter head pressure is available for distribution. Further away from the reservoir there will be gradual loss in pressure because of the pipe network, presence of valves, meters, change in the size of the pipelines among other things. These frictional losses will add up and the available pressure would be much lower.

At some point, it would be even lower than the 12 meter which is the minimum value that has to be provided as per standards. This means we have to have 12 meter head pressure at the endpoint. So, at the extreme end of the delivery network; for a particular service reservoir, the pressure in the pipe should be around 12 meters so that the water would be able to rise to a height of 3 storeys. So, this is usually the way we design the service reservoirs.

The two purposes of a service reservoir are; the first purpose is to balance the fluctuating demand and the second purpose is to provide the appropriate pressure required in the distribution system. Sometimes the pressure changes because of the number of connections that are turned on at any point of time. So, these fluctuations can be taken care because of this overhead tank. This also allows the source to give output at a different rate or in a steady rate. Since the supply rate and the discharge rate would be different, the source can give output at a steady rate; that means, the supply could be at a steady rate where a discharge could be at different rates.

A service reservoir actually stores water to also meet fire and other emergency demands. Emergency demand is when there is a failure in the system when something has broken down and has to be repaired. During this time period, the service reservoir would be able to serve the downstream distribution network. So, fire demand and emergency demand are also taken care by the service reservoir.

Coming to the design of service reservoirs, there are different types of service reservoirs. Usually, they have different compartments because whenever we are dealing with distribution networks and service reservoirs which are responsible for supplying water to large areas, we cannot afford a breakdown or a maintenance time for this. So, we have multiple compartments inside the service reservoir which facilitates the maintenance and operation simultaneously. That means, operation continues from one compartment while the other compartment is being cleaned or maintained. This helps in keeping the entire system operational while carrying out maintenance and cleaning procedures.

Service reservoirs are prone to act of vandalism and terrorism. So, we should be very careful when we set up a service reservoir at certain points where people can inflict damage. Apart from that, the service reservoir and the surrounding landscape have to be built aesthetically such that it doesn't look out of place in the urban environment.

The depth for service reservoir can also be optimized for different storage capacity which will we discussed towards the end of the lecture. As per standards, in case of overhead tanks usually for around 1000 kilo litres of water, the Indian Government of India suggests around 3.5 to 5 meters should be the depth of that overhead reservoir.

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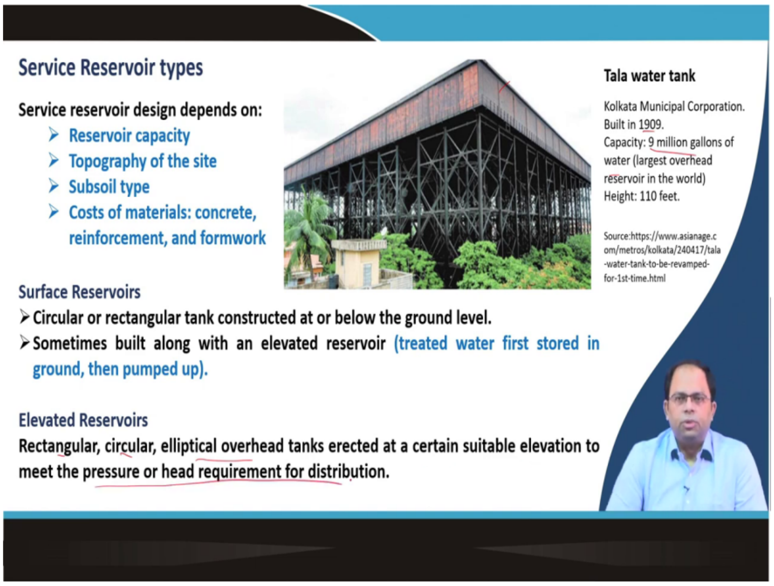


**Service Reservoir types:**

So, there are different kinds of service reservoirs. This particular image is of the Tala water tank which is the largest water reservoir of the world. It is at a height of around 110 feet and is operated by the Kolkata municipal corporation. It was built in 1909 which was during the British period and the capacity is around 9 million gallons of water.

This is not a concrete reservoir and is made of steel and iron. In today's context we never find this kind of large-scale reservoirs. But because it was done much earlier it was constructed like this.

Service reservoir design depends on the reservoir capacity; that means, for certain capacities certain shapes are beneficial. Rectangular shape is not beneficial for large reservoirs, but in the case of Tala water tank because it is so large and because of the size of the site and shape of the site probably this was thought to be the most efficient design then.

The topography of the site plays a role in the design of service reservoir shape. If the subsoil is able to take load, then we will design a certain kind of service reservoir. Then cost of materials such concrete, reinforced concrete or reinforcement or the formwork also determines what kind of service reservoir or its height.

So, service reservoir could be circular or rectangular tanks constructed at or below ground level. Basically, we can have an overhead reservoir or we can have reservoirs at the ground level. But some reservoirs which are at ground level or below ground level will be coupled with an elevated reservoir. That means, after the water is treated in a treatment plant it is first stored in a ground level reservoir and from there it is pumped to an elevated reservoir.

That means, after treatment we can directly pump it into an overhead reservoir or an elevated reservoir and this could be of different shape such as rectangular, circular, elliptical. These are erected at certain suitable elevation to meet the pressure or the head requirement for distribution.

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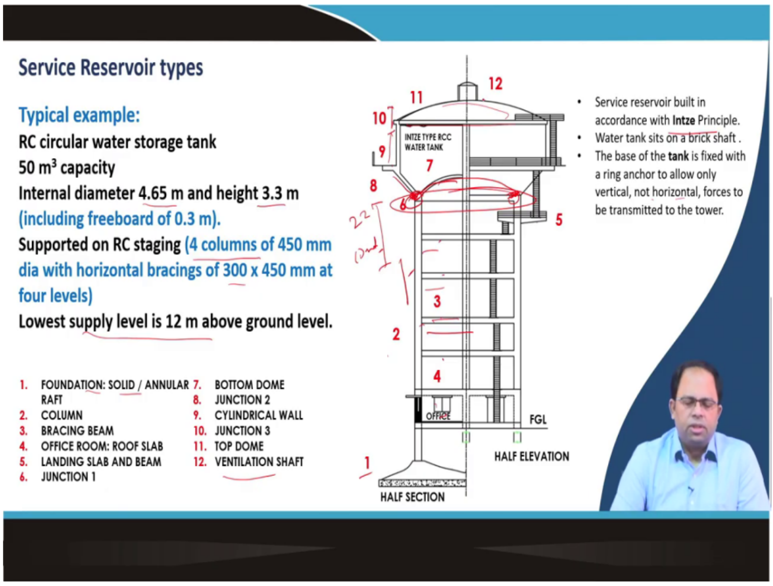


This is an example of a reinforced concrete circular water storage service reservoir. This particular reservoir is of 50 meter cube capacity. The internal diameter is around 4.65 meter and height of 3.3 meter and out of that 0.3 meter is the freeboard which is the top clearance. This is supported on reinforced concrete staging. There are 4 columns of 450 millimetre diameter with horizontal bracing of 300 to 450 mm at four levels.

The lowest supply level is 12 meters above ground level so; that means, the overhead tank should be able to provide water and the minimum pressure would be 12 meter. But we can raise the overhead tank to around 20 - 22 meters, so that we can have that extra gap of 10 meters for overcoming frictional losses during travel of water in the distribution network. This is how we usually design water supply service reservoirs in residential areas.

This particular service reservoir is built in accordance with the Intze principle. So, these are also known as Intze tanks or Intze reservoirs as well. The basic principle is to support the movement of water inside the tank during earthquakes and other hazards. This generates both horizontal and vertical forces in this particular tank. But we only want the vertical forces to be transferred through columns. Because these are tall designs and if the horizontal forces come in, then it may result in cracks in the columns and other damages. So load is transferred through a ring anchor to allow only vertical load and not horizontal forces to be transmitted to the tower. This is the basic design of a reinforced concrete circular water storage tank which we usually find in our urban areas.

1 is the foundation which is a solid or annular raft foundation, 2 are the columns, 3 is the bracing beams, 4 is the office room, 5 is the landing slab, 6 is a junction, 7 is the bottom dome, 8 is another junction, 9 is the cylindrical wall, 11 is the top dome, 12 is the ventilation shaft. So, this is the typical design of a service reservoir. We can go up and check the water levels or perform some maintenance tasks and operations.

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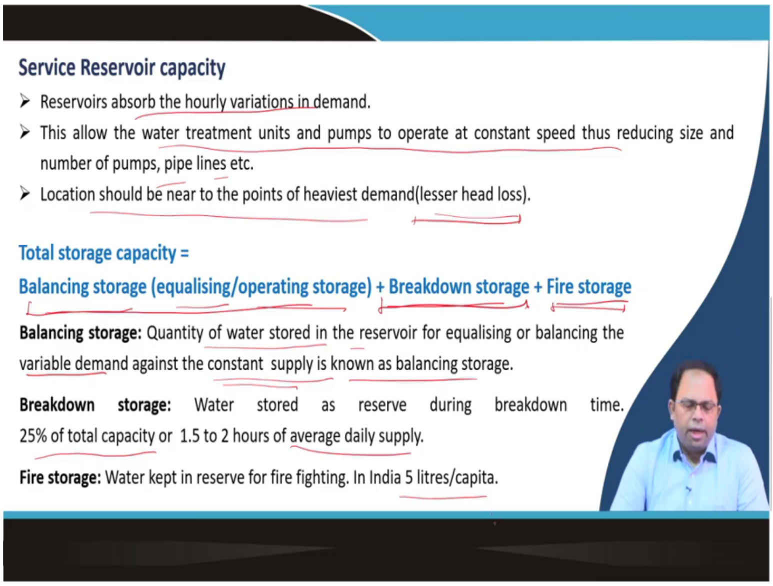


**Service Reservoir Capacity**

The capacity of service reservoir needs to be determined. The size required for a particular urban area or a particular zone which this particular service reservoir can serve is determined considering a few things.

First of all, the service reservoir should be able to absorb the hourly variations in demand. Based on the number of times pumps will operate in a particular distribution network. A service reservoir should be able to handle the water requirement for 8 hours for a particular community which is the minimum; it can also be 12 hours or 24 hours depending on the frequency of pumping. But during the time the pumps are being operated there is also consumption.

So, if we consider this incoming water and outgoing water and only store the water which is required, the total reservoir capacity actually comes down. If we just take the total demand for 8-hour period and store it, it will require a much larger capacity. But if we consider the incoming water and the outgoing water and only that balance water is being stored, we store lesser amount of water. So, that is why reservoir is used for absorbing these hourly variations in demand both for supply and demand and accordingly we can determine its size.

As we discussed earlier, these reservoirs also allow water treatment units and pump to operate at constant speed, thus reducing size and number of pumps, pipe lines etc. So, pumps usually operate at fixed speed at different time periods. Whereas, the demand or the water going out of the reservoir would be varying, because at different time periods people consume different volumes of water. And the location of the service reservoir should be near to the points of heaviest demand so that the head loss would be minimum.

Therefore, it is centrally located in the zone it is serving so that the total distance of pipelines(and resulting headloss due to friction) to the extreme edges would be the least. The height of the reservoir also depends on the amount of head loss that will happen.

So, total storage capacity is balancing storage, also known as equalising storage, and operating storage. So, this balancing storage is determined based on the incoming water and the outgoing water and the breakdown storage plus the fire storage. So, overhead tank is responsible for storing water to fight fires and in case of breakdowns.

So, balancing storage is the quantity of water stored in the reservoir for equalising or balancing the variable demand against constant supply and is known as balancing storage.

Breakdown storage is the water stored as reserve during breakdown time which is usually taken as 25 percent of the total capacity or 1.5 to 2 hours of average daily supply, whichever is greater.

Then fire storage is the water kept in reserve for fire fighting. In India it is about 5 litres per capita.

$$Total\ storage\ capacity\ =\ Balancing\ storage\ +\ Breakdown\ storage\ +\ Fire\ storage$$

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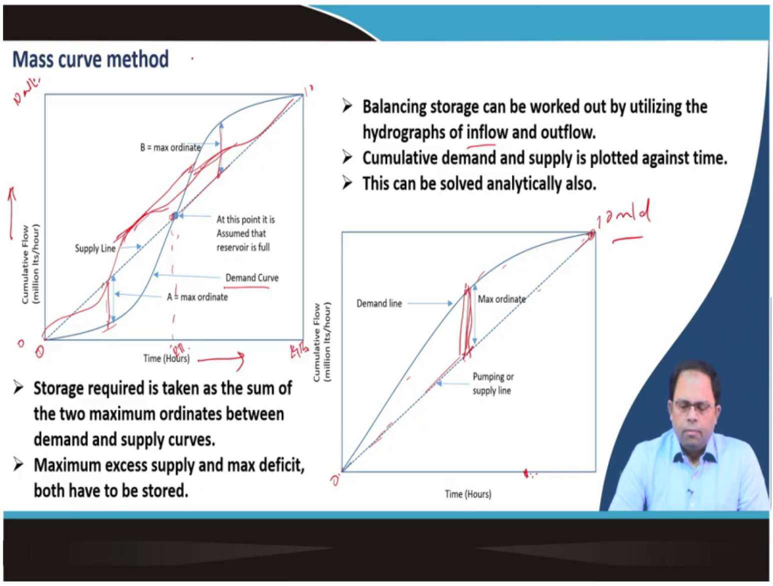


**Mass Curve Method**

How do we measure this balancing storage or what is the volume of water that needs to be stored considering the volume of water that is coming in and the volume of water that is going out? Several methods can be followed. First the mass curve method is discussed.

In the x axis we have got time which is in hours and the y axis we have got flow which is in cumulative flow in million litres per hour. So, you can see two lines in this graph; one line is the supply line and another line is the demand curve. Now, over here in this particular image the supply line starts from 0. The start time is assumed to be morning 6 o' clock(any time is fine) and same for every hour. That means, the pumps continuously operate at the same speed all throughout the day which is usually not the case. The total volume of water or the cumulative flow is assumed to be 10 million litres which is supplied starting from 0th hour till the 24th hour; if we consider 1 day. Joining 0 and 24 we get a straight line which is the supply line because of uniform pumping.

Next, we see that demand is gradually increasing and because it is cumulative the curve becomes flatter when demand is low and then again it rises and becomes flat. But at the end of the day the demand is also same as the supply because whatever you supply that is amount that is consumed.

But during this time, we can see that at some point of time the demand has actually crossed the supply. So, what does this mean? So, we can say that at this point the cumulative demand is same as supply. That means, from 0th hour to 12th hour, the demand is higher and supply is less. Eventually supply catches up. Since demand is high during this period, we need to keep water stored from before otherwise we would have run out of water.

Similarly, in the next period, supply is more and demand is less which means we have to store this amount of water as well. Because if not stored, where would this excess supply go? So, both the excess supply and the excess demand needs to be stored. Thus, based on both the maximum of the deficit period and excess period balancing storage is computed.

Balancing storage can be worked out by utilizing the hydrographs of inflow and out flow. Hydrograph is the cumulative flow graph. Both inflow and outflow can be fluctuating. Unlike the earlier example, supply in a dam is not continuous. Cumulative demand and supply is plotted against time to determine the balancing storage. This can be solved analytically or we can do it following the mass curve method. The storage required is taken as the sum of the two maximum ordinates between the demand and supply curves for both the deficit and excess period.

Now, in case the cumulative demand is always more than supply( of course, eventually it is same as supply) and rate of pumping is uniform, there is only one ordinate because there is only the deficit period. So, the reservoir is always at deficit; that means, this excess water has to be stored. At the end of the day, entire supply is being consumed. So, next day we start with this volume of water which is the capacity of that particular reservoir.

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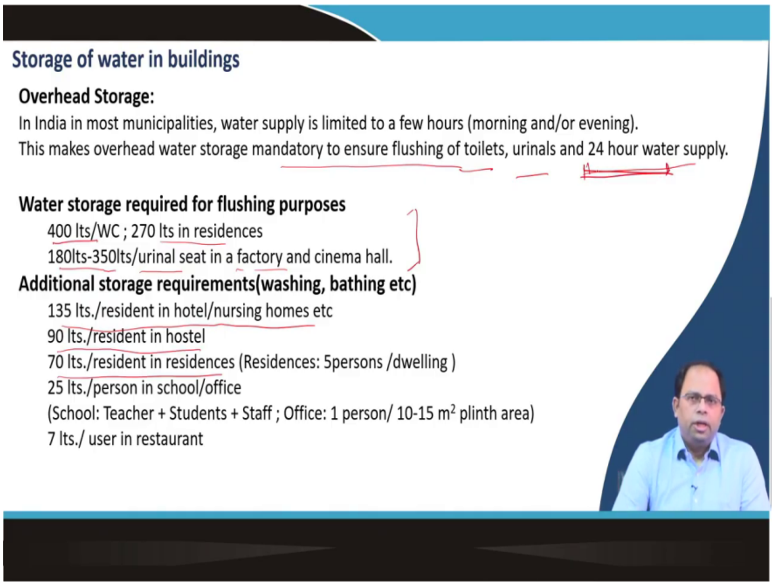


**Storage of water in buildings**

Similar to a zone, variation in water demand is also present inside a building. But we ignore this when we design the overhead reservoirs within the building. Similarly for a small area we can ignore the variation in demand and store whatever amount of water that is required for a 8-hour period.

Overhead storage is required in buildings because water supply is limited to only a few hours in most Indian municipalities. This ensure all day flushing of toilets, urinals and 24-hour water supply to other outlets.

So, if we only have water supplied to the urinals and the WCs, then the water requirement for storage inside the building is around 400 litres per WC or 270 litres in case of residences, 180 litres to 250 litres per urinal seat either in a factory or in a cinema hall depending on where the case may be based on Bureau of Indian standards. Based on building types, storage requirement for washing and bathing is 135 litres per resident in hotel or nursing homes, 90 litres per resident in hostels, 70 litres per resident in residences.

So, based on the actual water demand for that particular building, the capacity of the overhead tank can be determined. Usually it is assumed that the building pumps are run for only one time a day; that means, the overhead tank have to have a supply of water for 24 hours.

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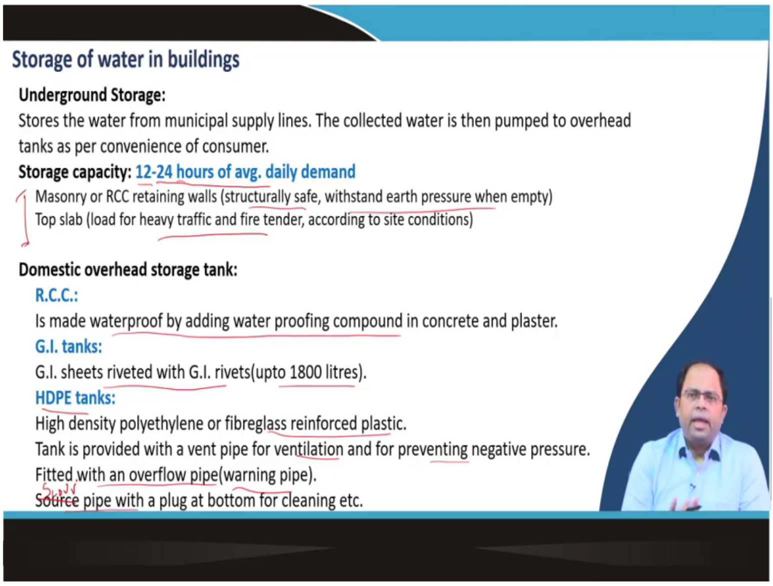


Underground storage in buildings stores the water from municipal supply lines. Whenever the water comes from the municipal lines, through ferrule, first, the water is collected in underground reservoir and then it is pumped to the overhead reservoir. If the pump is run twice then the reservoir capacity has to be for 12 hours and if it is run only once a day then the reservoir capacity has to be for 24 hours of average daily demand.

Both the underground reservoirs and overhead reservoirs are designed following the same principle. And in case of underground reservoirs, it is a masonry or RCC reservoir and it should be structurally safe and be able withstand the earth pressure when the reservoir is empty. The top slab has to be covered and it should be able to take heavy traffic load(fire tender) during an event of a fire.

An overhead reservoir can be made of concrete, galvanized iron, high density polyethylene or plastic. RCC tanks has to be made waterproof by adding waterproofing compound in the concrete and also in the plaster. GI tanks or galvanized iron tanks made of GI sheets which are riveted and can hold water up to around 1800 litres. High density polyethylene tanks are the ones which we see in most houses these days. These are fibre glass reinforced plastic and tank is provided with a vent pipe for ventilation at the top for preventing negative pressure. An overflow pipe is also provided. There is a bottom scour pipe with a plug at the bottom for cleaning the tank.

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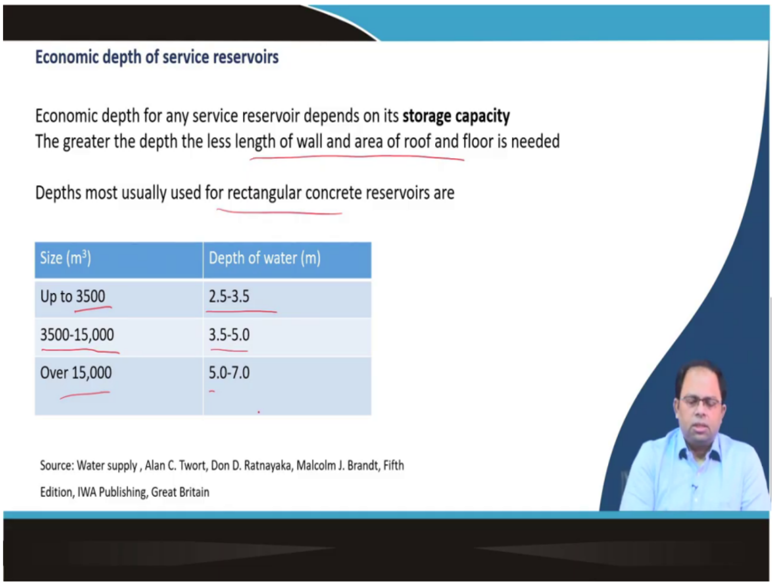


**Economic depth of service reservoirs**

As per Government of India, the depth to be provided for overhead reservoirs of 1000 meter cube capacity is around 3.5 meters up to 5 meters. But as per international standards, for rectangular concrete reservoirs of 3500 meter cube capacity, the suggested depth is around 2.5 to 3.5 metres, for 3500 to 15000 meter cube, the depth is 3.5 to 5 meters and over 15000 it is around 5 to 7 meters.

More is the depth, less would be the length of walls and area of the roof and floor which influences the cost of construction. It is both costlier to increase the depth or increase the length and area. So, based on these factors, we find the economic depth or the optimum cost.

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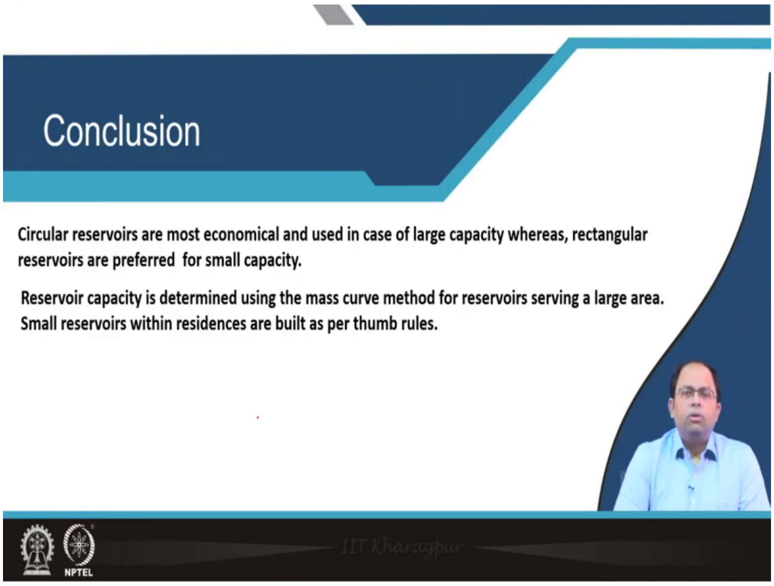


So, in conclusion we can say circular reservoirs are most economical and used in cases of large capacity. Whereas, rectangular reservoirs are preferred for small capacity. Reservoir capacity is determined using the mass curve method for reservoirs serving a large area. Small reservoirs within residences are built as per thumb rules.

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So, these are some of the references that you can study.

Thank you.